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Digital 3d Collections of Mosaics.

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Abstract: In this paper we present a methodology developed to access to Cultural Heritage information using digital 3d reality-based models as graphic interfaces. The case studies presented belong to the wide repertoire of mosaics of Ravenna, ranging from the byzantine to the modern ones. One of the most peculiar characteristics of mosaics that often limits their digital survey is their multi-scale complexity; nevertheless their models could be used in 3d information systems, for digital exhibitions, for reconstruction aims and to document their conservation conditions in order to conduct restoration interventions in digital environments aiming at speeding and performing more reliable evaluations.

Keywords: range and image-based technologies; 3d modeling; mosaics; digital collections; knowledge sharing.

Introduction and aims

The aim of enlarging knowledge disseminating Cultural Heritage contents to a wide audience can sensibly benefit from the recent advances in the field of visualization techniques and Internet technologies. In particular, thanks to the communication's effectiveness of 3D models, conceived and built as digital replicas of reality, 3D data can be used as highly intuitive graphic interfaces to visualize and share different kinds of information. But although several technologies and methodologies for 3d digitizations have been developed and improved in the last two decades (Bernardini and Rushmeier, 2002; Blais, 2004; Pavlidis et al., 2007; Remondino, 2011), the lack of a standard procedure that guarantees the consistency and the durability of digital data that need to be used in different contexts and for different purposes that can change through time and the costs connected to their use still don't encourage the systematic digital acquisition of wide collections and heritage. For these reasons, artifacts and artworks which present evident intrinsic complexities such as, for example, mosaics, are still not widely investigated.

In this paper we present a methodology developed to access to Cultural Heritage information using digital 3D reality-based models as graphic interfaces and information repositories. In particular, the case studies presented belong to the wide repertoire of mosaics of Ravenna, ranging from the byzantine to the modern ones.

One of the most peculiar characteristics of mosaics that often limits their 3d digital survey is the complexity of their geometry that can be detected at two main scales of observation. Looking at an overall scale, mosaics generally cover floors or walls which have predominant two-dimensional geometries that can be assimilated to flat or curved (vaults, columns, etc.) surfaces. At a smaller scale, mosaic surfaces are constituted by single tesserae whose geometry is very complex and therefore needs to be acquired using more accurate instruments and methodologies. In addition to these aspects, as far as their colour and reflectance characteristics, the use of translucent materials (such as glass or marble) and metal finishing (gold leaf) of tesserae, can underline lacks and difficulties when collected using technologies that use light as mean to recognize the position of 3d points in space (Salemi et al., 2008).

One of the most immediate applications of digital 3d survey of mosaics is the substitution of plaster casts which are usually required by Superintendences in order to add the third dimension to pictorial or photographic surveys before restoration interventions. Some of these pictorial surveys - the so called "cardboard mosaics" - show an evident ability and accuracy in the reproduction of shapes, color, transparence and reflectance characteristics and are considered, themselves, artworks to be

exhibited in museums collections. The possibility to superimpose these cardboards on 3d geometry of mosaics in a digital environment represents an opportunity to stratify different kinds of information about a single artifact (Fig. 1).
In addition to this purpose, digital 3d surveys of mosaics allow to document their conservation conditions and to conduct restoration interventions in a digital environment and therefore to speed and perform more reliable evaluations. Moreover, 3d reality-based models of mosaics can be used in 3d information systems or for digital exhibitions and reconstruction aims. When mosaics completely envelop inner spaces their digital representation re-builds the image of the entire architectural space.

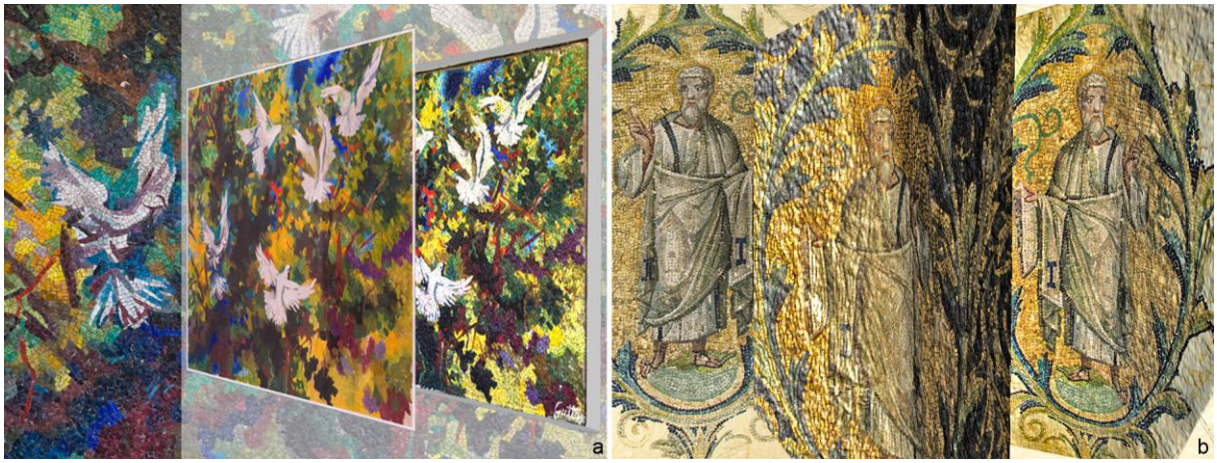

Fig. 1. Superimposition of different information in a digital environment. (a) preparatory cardboard painted by Renato Guttuso in 1959; (b) byzantine mosaic and survey painting.

Complexities and challenges

Beside its unique heritage of byzantine mosaics, Ravenna also hosts a collection of modern mosaics ("Modern Mosaics Exhibition") that have been designed and built in 1959. Artworks by artists such as Marc Chagall, Renato Guttuso, Roberto Signorini and Michelangelo Antonioni belong to this collection. Despite their recent creation, some of these mosaics have already been or are planned to be restored in a short time. These restoration interventions require preliminary survey campaigns aimed at documenting their conservation conditions through the collection of different kinds of information. This recognition generally uses thematic tables based upon graphic representations (pictorial or photographic surveys) in order to collect and link these different information. During last century, on the occasion of some specific restoration campaigns, the Superintendence of Ravenna required the building of plaster casts in order to add spatial consistency to pictorial surveys. As a matter of fact, one of the limits of traditional bi-dimensional representations mainly consists in their extreme synthesis, which leads to a significant reduction of information. Mosaics are not only made of connective tissue, paint films and tesserae; they have a support structure whose geometry and conservation conditions remarkably influences restoration results. This aspect is particularly important in the case of modern mosaics, that have evident intrinsic three-dimensionality, both at a small and at an overall scale.
Unlike mosaics belonging to the Modern Exhibition, that are constituted by rather small and movable artworks, byzantine mosaics generally cover wide portions of inner walls or ceilings; as a consequence of their extension and of the planarity of their tesserae and mortar (Fig. 2), their small scale details are less significant that the ones that characterize modern mosaics.
The evaluation of these aspects was fundamental for our research, aimed at finding the most appropriate digital methodology and procedure to adopt in order to collect reality-based information upon mosaics able to straightforward both the preservation of the consistency of information and the management of huge amount of data.

Fig. 2. Details of a modern (a) and byzantine (b) mosaic.

Our methodology

Within our approach, after the preliminary analysis of geometric and chromatic characteristics of mosaics, we defined different aims, ranging from simple visualizations of the whole artifact via the web or digital reconstructions for popular aims, to accurate analysis and metric evaluations of reliefs, placement and orientation of single tesserae conducted by scholars and restorers. As a consequence, we singled out different scales of investigations related to our purposes and therefore defined the most appropriate technology to adopt.

As far as modern mosaics are concerned, we distinguished two main levels of details related to these aims and tested different acquisition technologies and methodologies. The most detailed survey required the use of triangulation laser scanners that are usually suitable for the acquisition of small artefacts and are able to provide high resolution and accurate surveys. In particular, we tested the Konica Minolta Vivid 900 and the Perceptron ScanWorks V4i with ROMER Omega bracket triangulation laser scanners. Each of them showed advantages and disadvantages during acquisition and post-processing of data. In particular, ScanWorks V4i allowed to acquire the most detailed information and meanwhile to drastically reduce survey and post-processing time, as it directly aligns single patches to one reference system. This allowed to verify the covering of the whole acquired surface and eventually fill lacks directly during survey campaign. On the other hand, particular attention was paid to the right distance from the artifact, as this scanner has a very small depth of field if compared to the Minolta one (109 mm vs ~ 2500 mm). This characteristic is rather constraining in case of modern mosaics that are affected by evident occlusions.

The collection of law detailed information about modern mosaics to be used for simple visualizations via the web was both derived by applying simplification algorithms on detailed information and acquired testing the Leica HDS6100 phase-based laser scanner (Fig. 3) and Menci ZScan image-based technology. While the phase-based technology allowed to drastically reduce survey time, it also required the acquisition and alignment of geometric information with high definition images. The second approach directly provides both information at the same time.

These last two technologies highlighted evident advantages when used on byzantine mosaics that are generally characterized by less evident occlusions and by small scale details that have a secondary importance if compared to the large scale ones. In addition, the location and extension of byzantine mosaics generally don't allow to observe the right distance required by triangulation laser scanners, as a consequence, phase-based and image-based technologies provided the best performances.

Besides these aspects, one of the main goals of our methodology was to reduce redundant data and therefore ease the management of huge amount of information. As a matter of fact, some of the main problems of high definition 3d surveys are memory requirements and computational costs. In order to overcome these problems, post processing simplifications of detailed geometry using different decimation algorithms and simplification intensities have been performed in order to reduce redundancy of data without losing surface irregularities and singularities. These results have been compared with acquisitions conducted using less accurate and precise technology, in order to evaluate the most suitable procedure to contain the heaviness of files and ease the management of data (Manferdini et al., 2011).

Fig. 3. Phase-based 3d scanner of mosaics of Battistero Neoniano in Ravenna.

Discussion and conclusions

This contribution shows how Museums and Institutions called to preserve and promote their artistic and architectonical heritage can benefit from the use of digital technologies. In particular, in the case study of mosaics, restoration planning and interventions, as well as documentation collections can be significantly improved thanks to the possibility to build their digital replicas and therefore provide more complete and flexible information about them.

The challenges of the present research are represented by the richness and multi-scale levels of detail of the artifacts, by the radiometric characteristics of their matter, by the management of huge amount of data and by the preservation of details during visualizations.

The different peculiar characteristics of modern and byzantine mosaics highlighted advantages and disadvantages in the use of range-based and image-based survey methodologies.

Comparisons among the results obtained using both approaches in different case studies showed that when the architectural scale is predominant than the small one, as for example, in case of byzantine artifacts, image-based technologies are privileged, as they directly and automatically supply metric information with high resolution images. Some range-based technologies, such as phase-based laser scanners, allow to provide analogous results, when integrated with high resolution cameras. In these case studies, these two technologies provide the best solution in terms of accessibility to artifact, level of detail of the re-built model and possibility to manage huge amount of data.

As far as modern mosaics are concerned, their small scale details need to be acquired using different technologies following various degrees of complexity. As a consequence different versions of 3d models where built following this multi-scale approach. In particular, image-based and phase-based laser scanning techniques where adopted just for fast visualizations, while triangulation laser scanning was privileged in order to supply accurate and detailed information about the geometry of tesserae and mortar areas. In those cases studies, the need to handle huge amount of data collected using triangulation laser scanners was not a secondary challenge, that we faced through accurate preliminary analysis and evaluations on the most suitable resolution to adopt during survey campaign and post-processing simplifications aiming at preserving the quality of the mesh and meanwhile allow to manage information using current and widespread software and hardware technologies and performances.

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